VEGETATIVE TYPES AND ENDEMIC PLANTS OF THE BRYCE CANYON BREAKS

Robert A. Grayboscli[1] and Hayle Buchanan[2]

Abstract.— The scenic Bryce Canyon "breaks" constitute harsh and inhospitable habitats for plant life. The eroded pink cliffs and talus slopes are sites of some of the most rapid natural erosion on earth. This paper divides the plant life on the breaks of the main Bryce Canyon amphitheater into four vegetative types. A checklist of all plant species found in the main amphitheater is included. Many of the rare and endangered endemic species of the park are found in the *Pinus longaeva* vegetative type. Recommendations for managing the breaks to protect endemics are presented.

The breaks community is one of the six major plant communities of Bryce Canyon National Park as described by Buchanan (1960). It consists of a relatively narrow band of unvegetated or sparsely vegetated badlands formed by the red beds of Claron (Wasatch) formation along the eastern edge of the Pausaugunt Plateau. This paper represents the results of a study of the main amphitheater of Bryce Canyon to define the vegetative units.

Intricate erosional formations can be viewed from Sunrise, Sunset, Inspiration, and Bryce viewpoints. The diverse topography and beauty of the formations attract thousands of park visitors to the viewpoints and rim trails, although relatively few of them venture into the main amphitheater. The majority of hikers and horse riders who traverse the breaks remain on well-maintained trails, and thus have relatively little impact on the plant communities.

The flora of Bryce Canyon is rich in species endemic to the High Plateaus of southern Utah (Welsh and Thorn 1979, Buchanan and Grayboseh 1981). Several of these threatened and endangered plant species have limited populations in the main Bryce Canyon amphitheater. Preservation of such species depends on recognition of preferred habitats and provision of means to protect them from visitor impact.

Description of the Study Area

Bryce Canyon National Park is located on the eastern edge of the Pausaugunt Plateau in south central Utah. The Pausaugunt Plateau occupies a position midway between 37° and 39° north latitude 10 miles west of the 110th meridian. The boundaries of the main amphitheater circumscribe the drainage system of Bryce Wash, an intermittent tributary to the Paria River, an area 4.5 km^2. The boundaries differ somewhat from those considered by Lindquist (1977) and Buchanan and Graybosch (1981). Elevations within the study area range from 2,200 to 2,530 m (7,250–8,300 ft). The study area lies along the western border of the Kaiparowits Basin, the flora of which was reported by Welsh et al. (1978).

The geologic stratigraphy of the study area is reported by Brox (1961), Anderson and Rowley (1975), Doelling (1975), and Lindquist (1980). The Claron limestone, a Tertiary deposit, is divisible into Red Eocene beds and White Oligocene beds, which differ somewhat in presence or absence of pigmentation in the form of iron and manganese oxides, and in amounts of sand and conglomerates in the limestone. The Claron formation is characterized by a rapid rate of erosion, largely a function of creep resulting from winter freeze-thaw activity and wash-

[1]Department of Genetics, Iowa State University, Ames, Iowa 50011.
[2]Department of Botany, Weber State College, Ogden, Utah 84408.

away by summer thunderstorm runoff. Freeze-thaw cycles are most pronounced on south-facing slopes. Soil development is limited.

Climatic features of the study area may be inferred from weather records kept at park headquarters, 2 km from the main amphitheater. The average annual precipitation is 41 cm, falling largely in the form of winter snow and late summer thunderstorms. Mean January maximum temperature is 20 C; mean July maximum temperature is 27 C. The mean January and July minimum temperatures are -13 and 7.6 degrees C, respectively. The main amphitheater is generally more xeric than these values indicate (Buchanan 1960), with higher temperatures and a greater evaporative capacity of the air prevailing. Water availability to plants is decreased on the predominantly dry substrates, which have low infiltration rates and high runoff. Ravines and north-facing slopes within the main amphitheater are probably more hydric than the adjacent plateau forest at park headquarters.

Methods

The vegetation of the study area was surveyed by means of 100 × 100 m^2 plots. Plots were subjectively placed in areas of homogeneous vegetation among the clifflike formations. Within each plot, density and basal area of all mature trees (over 5 cm dbh) and density only of juvenile trees (less than 5 cm dbh) were recorded. An importance value was formulated for mature trees by summing the relative values of density and basal area. Understory vegetation was surveyed through the use of four 10 m line intercepts, placed at 2 m intervals. Importance values for understory herbs and shrubs were determined through the summation of the relative values of density, dominance, and frequency. Understory species present in plots but failing to contact the survey lines were recorded as being present and this information was used in determining the relative frequency values.

Using the importance values of dominant species, plots of similar composition were grouped together to define vegetative types. The mean importance values for all species in each type were determined, and comparisons were made between types for all species having a mean importance value of greater than 1.0 (all trees, five shrubs, and seven herbs) using Sorensen's Index of Similarity (Sorensen 1948).

All species present in the study area were recorded and assigned to vegetative types when possible. Voucher specimens are on file in the herbarium of Bryce Canyon National Park. Nomenclature employed is that of Welsh et al. (1981).

Results and Discussion

A complete list of species occurring in the main amphitheater is presented in the Appendix. Two species, *Puccinellia nuttalliana* and *Schizachyrium scoparium*, are additions to the flora of Bryce Canyon as reported by Buchanan and Graybosch (1981). Additions to the flora of the Kaiparowits Basin, based on Welsh et al. (1978), are noted in the Appendix.

Data to be presented below allows the division of the breaks (as it occurs in the main amphitheater) into the following vegetative types. Some of these are variable and are further divided into phases. Each shall be discussed in turn.

1. *Pinus ponderosa—Arctostaphylos patula* type (Pipe-Arpa type)
2. *P. ponderosa—A. patula* type, *Cercocarpus montanus* phase (Pipo-Arpa type, Cemo phase)
3. *P. ponderosa—Pseudotsuga menziesii* type (Pipo-Psme type)
4. Mixed coniferous type, *Picea pungens* phase (MC type, Pipu phase)
5. Mixed coniferous type, *Abies concolor* phase (MC type, Abco phase)
6. *Pinus longaeva* type (Pilo type)
7. Washes, clay and talus slopes

Table 1 summarizes the dominant species of each vegetative type in terms of mean importance values. A similarity matrix is given in Table 2, comparing the various types and phases.

Description of Types and Phases

1. Pipo-Arpa Type

Occurrence: Canyon bottoms and south-facing slopes between elevations of 2,200 and

TABLE 1. Dominant species (in terms of mean importance value) in each vegetative type and phase. Types and phases are given the numerical designation employed in the text.

	Type or phase					
Species	1	2	3	4	5	6
Trees						
Abies concolor mean					81.7	
s.d.					33.3	
Juniperus scopulorum	29.3	27.2	13.0	24.2	25.8	
	37.9	24.2	21.4	27.2	29.7	
Picea pungens	2.3			89.7	25.3	
	8.1			36.3	29.7	
Pinus flexilis	7.6		17.2	22.5	3.0	44.9
	23.6		23.1	31.5	6.6	48.4
Pinus longaeva	1.0			4.0		128.3
	5.9			19.2		71.3
Pinus ponderosa	158.8	172.8	102.1	35.2	35.5	8.6
	43.9	24.2	45.6	36.0	29.6	16.8
Pseudotsuga menziesii	1.0		67.6	25.9	28.8	
	4.4		48.1	25.1	24.9	
Shrubs						
Acer glabrum		3.2	19.4	19.1	19.8	
		7.9	29.8	25.9	23.9	
Amelanchier utahensis		20.2	1.3	1.8		
		31.3	4.7	5.1		
Arctostaphylos patula	85.6	14.1	70.9	57.9	19.7	76.8
	32.0	18.6	58.1	40.7	40.5	43.7
Ceanothus martinii	12.2	4.5	7.0	8.9	2.0	2.2
	13.0	7.3	7.9	9.2	4.5	7.3
Cercocarpus montanus	5.4	138.0		23.6	30.1	2.2
	13.8	49.7		50.2	46.8	7.2
Juniperus communis	2.1			19.1	34.4	4.4
	6.9			25.9	46.8	7.2
Mahonia repens	35.7	15.9	46.7	50.3	89.6	1.5
	27.3	26.2	39.6	40.5	60.1	3.3
Purshia tridentata	1.0	1.2		1.4	16.1	
	2.5	2.9		4.4	46.1	
Ribes cereum			1.7			
			5.6			
Xanthocephalum sarothrae	1.9					1.0
	4.9					1.7
Grasses and forbs						
Astragalus kentrophyta					1.0	
					1.7	
Cirsium arizonicum	6.4		3.9	4.0	1.4	3.9
	6.7		6.5	6.6	4.7	5.8
Clematis columbiana	1.9		2.1	4.0		
	4.4		3.3	6.6		
Crytantha abata	2.7	3.5				
	4.6	3.5				
Cymopteris purpureus						7.2
						7.4
Elymus salina	34.4	4.0	36.6	13.7		5.3
	34.8	9.9	32.9	19.7		10.5
Eriogonum panguicense						11.8
						10.4

Table 1 continued.

Species	Type or phase 1	2	3	4	5	6
Haplopappus armerioides	5.9 11.0	2.6 6.2	2.0 7.1	1.0 2.6		6.4 8.8
Hymenopappus filifolius						7.9 13.8
Ivesia sabulosa						14.2 19.4
Linum kingii						17.9 14.7
Lithospermum multiflorum	6.7 8.9	1.3 3.1	2.0 3.2			
Machaeranthera grindelioides						6.7 7.0
Oenothera brachycarpa	4.4 4.4		1.5 2.5			
Oryzopsis hymenoides	13.6 10.2	1.7 4.2	4.8 10.1	11.1 12.9	1.0 3.2	10.7 9.6

2,400 m, continuing to lower elevations outside the study area. Occurs on substrates derived from both the Claron formation and Quarternary alluvium.

Vegetation: The dominant tree is *P. ponderosa*, with *Juniperus scopulorum* and *Pinus flexilis* as common associates. Thickets of *Quercus gambelii* occur, although infrequently. The shrub layer is dominated by *A. patula*, with *Mahonia repens* and *Ceonothus martinii* of secondary importance. The most common herbs are *Elymus salina* and *Oryzopsis hymenoides*. In contrast to the ponderosa pine forests of the adjacent plateau, *Purshia tridentata* is rare. A total of 65 species occurs in this type, several being restricted to it. There are largely taxa (i.e., *Mahonia fremontii, Streptanthus cordatus*, and *Euphorbia fendleri*) that are nearing their upper elevational limits in the study area.

Relation to other types and phases: Closest resemblance is seen between this type and the Pipo-Psme type and the Pipo-Arpa type, Cemo phase. It forms ecotones with all other types, as well as with a woodland of *Juniperus osteosperma, Pinus edulis*, and *Quercus gambelii* at the lower elevational limits of the study area.

2. Pipo-Arpa type, Cemo Phase

Occurrence: Adjacent to washes, on alluvium, between elevations of 2,200 and 2,300 m.

Vegetation: The dominant trees are *P. ponderosa* and *J. scopulorum*, with an understory dominated by *Cercocarpus montanus*. *Amelanchier utahensis* is an additional frequently encountered shrub. *Arctostaphylos patula* is infrequent and variable in importance values. Herbaceous vegetation is uncommon.

Relation to other types and phases: This particular phase exists only in narrow bands adjacent to washes and is generally surrounded by the Pipo-Arpa type in its typical manifestation. Possibly recognized as a distinct type if more widespread, it is most closely related to additional types dominated by *P. ponderosa*. The importance values of *P. ponderosa* and *J. scopulorum* are nearly identical in plots assignable to this phase and those in the typical Pipo-Arpa type (Table 1). This phase probably exists as a result of periodic flooding, with subsequent alteration of the physical features of the substrate. This provides a microhabitat that evidently favors *C. montanus* over *A. patula*, but does not influence the nature of the canopy.

3. Pipo-Psme Type

Occurrence: North-facing slopes of the Claron formation between elevations of 2,285 and 2,380 m. Soil development is extensive due to limited winter freeze-thaw activity.

Vegetation: Dominance is shared by *P. ponderosa* and *P. menziesii*; *Pinus flexilis* is occasionally encountered. The principle shrub is *A. patula*, with *M. repens* a common associate. In several plots, however, the density of trees was of sufficient magnitude to exclude most understory species. A significant increase in the abundance of more mesophytic species (i.e., *Acer glabrum*, *Clematis columbiana*) is noted when this type is compared to the Pipo-Arpa type. A total of 38 species was found in this type.

Relation to other types and phases: Most closely related to the Pipo-Arpa type, this type also shows affinities with the phases of the MC type. Ecotones are formed with these communities.

MC Type

Occurrence: Canyon bottoms and steep north-facing slopes; substrates occupied are derived from both Red and White members of the Claron formation. Elevational distribution is between 2,285 and 2,450 m; the lowest elevation corresponds to the furthest extension of hoodoos. Ill-defined and somewhat polymorphic, this type is best described in terms of its two phases. Fifty-five species occur within this type.

4. MC Type, Pipu Phase

Vegetation: This phase is recognized by the consistent dominance of *P. pungens* in either pure stands or in mixed associations with additional conifers, the most common of these being *P. ponderosa*, *P. menziesii*, *P. flexilis*, and *J. scopulorum*. The understory varies from sparse along washes (where both *C. montanus* and *C. ledifolius* are frequent) to dense in plots not subjected to inundation. In the latter, *A. patula*, *M. repens*, *Juniperus communis*, and *A. glabrum* predominate.

Relation to other types and phases: This phase is most similar to the MC type, Abco phase. The differences between the two lie largely in the paucity of herbs and grasses in the Abco phase. Both are characterized by a high diversity of conifers, the primary difference between the two canopies being the identity of the dominant tree. Ecotones occur with the Pipo-Arpa type, the Pipo-Arpa type, Cemo phase, and the Pipo-Psme type. On upper slopes this phase gradually thins to relatively isolated individual trees.

5. MC Type, Abco Phase

Vegetation: Consistent dominance by *A. concolor*, and lack of dominance by *P. pungens*, is the hallmark of this phase. Most of the other conifers are common. Table 1 indicates *P. ponderosa* as having the second highest mean importance value. However, this phase is present on the White limestone where *P. ponderosa* is infrequent. In such stands, *P. menziesii* and *P. pungens* are the most common associates. Dominant shrubs are largely those of the Pipu phase, although *P. tridentata* is more common.

Relation to other types and phases: This phase is most closely allied to the MC type, Pipu phase. The two are separated spatially; the Abco phase occurs only on north-facing slopes and canyons east and north of the Wall-of-Windows, with an isolated stand in the Queen's Garden. It is possible that the Pipu phase represents an early seral stage of the Abco phase, although no juveniles of *A. concolor* were found in plots assignable to the Pipu phase. More likely, the two phases represent points along a moisture gradient. *P. pungens* seems able to exist in situations that are too dry to allow growth of *A. concolor*. The two phases do not form ecotones, except in the Queen's Garden. Here, *A. concolor* is found in a nearly pure stand in the shade of some isolated hoodoos. On more exposed sites at higher elevations in the same canyon it is absent, the area being dominated by *P. pungens*. Ecotones are recognizable between this phase and both the Pipo-Psme and Pipo-Arpa types.

6. Pilo Type

Occurrence: This type is well defined only on badlands of the Claron formation, espe-

TABLE 2. Matrix comparing vegetative types and phases through use of Index of Similarity (Sorensen 1948). Consult text for information on the numbering system.

	1	2	3	4	5
1					
2	58				
3	70	40			
4	51	31.5	61		
5	32.5	31	42	60	
6	33	9.6	32	30	11

cially on the ridgeline dividing the drainages of Bryce Wash and Campbell Canyon. There is no soil development; the substrate is generally clay-limestone overlaid by gravels or larger particles. The type ranges in elevation from 2,200 to 2,400 m. Bailey (1970) reports the lowest elevational record of *P. longaeva* as being 2,200 m.

Vegetation: P. longaeva in open stands is the usual appearance of this type. *Pinus ponderosa* and *P. flexilis* may also occur, all trees being twisted and stunted. It should be noted that *P. longaeva* does not attain the wide girth that one usually associates with the species (the largest specimen had a dbh of 22 cm). Because of this it is doubtful that it reaches the extreme ages of 4,000–5,000 years that have been reported (Cronquist et al. 1972). LaMarche (1969) mentions that the oldest reported bristlecone pine in Bryce Canyon is 1,560 years of age; the number of trees and their exact location was not given.

Shrubs are uncommon; only *A. patula* is of any real abundance. Understory vegetation generally covers less than 10 percent of the plots. The forb component differs from that of all other types; *Linum kingii, Ivesia sabulosa,* and *Eriogonum panguicense* var. *panguicense* are the most common. A total of 48 species was recorded for this type, several of which are typical of subalpine zones. Based on the distributions given by Cronquist et al. (1972), Dixon (1935), Ellison (1954), Harrington (1954), and Welsh and Moore (1973), these are: *Agropyron scribneri, Aquilegia scopulorum, Aster glaucodes, Erigeron simplex, Monardella odoratissima, P. longaeva, Potentilla fruticosa, Senecio attratus,* and *Silene pettersonii.*

Relation to other types and phases: As seen from the similarity matrix, this type has little in common with any others, the highest IS being 33. Ecotones are formed only with the Pipo-Arpa type, which extends up narrow washes draining the badlands.

7. Washes, Clay, and Talus Slopes

Much of the main amphitheater is devoid of vegetation or contains only infrequently encountered individuals of numerous species scattered about the eroding Claron formation. Structured plant communities tend to cluster in canyon bottoms, on the slopes of the wider canyons, or on rolling badlands. Species found on these barren areas have been recorded and are cited in the Appendix. Most of these slopes are not easily accessible; hence, the list may be incomplete. Plots were not used to survey such areas; if any pattern exists in the distribution of species, it has not been determined. The White beds form only vertical cliffs in the study area; plots were placed only on the Red member.

TABLE 3. Distribution of trees as a function of moisture availability. Types and phases are given in order of most xeric to most mesic. A = Pilo type; B = Pipo-Arpa type; C = Pipo-Arpa type, Cemo phase; D = Pipo-Psme type; E = MC type, Pipu phase; F = MC type, Abco phase.

Mean i.v.	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
0	+	+	+	+	+		+						+		+	+					+						+	+		+							+		+			
1–10														+						+				+		+			+		+							+				
11–20										+												+																				
21–30								+	+		+	+						+					+																		+	+
31–40																																			+	+						
41–50																			+																							
51–60																																										
61–70																																										
71–80																																								+		
81–90						+											+																									
91–100																																										
101–110																																		z								
111–120																																										
121–130																									+																	
131–140																																										
141–150																																										
151–160																																+										
161–175																																	+									
Species	Abco						Jusc						Pipu						Pifl						Pilo						Pipo						Psme					

Environmental Factors Influencing Distribution of Types

At this point, it can only be speculated as to which environmental parameters are most critical in determining distribution of species. Moisture availability and solar insolation may be critical, but variation in substrates may also warrant consideration. Based on topography, substrate, and exposure, it is believed that moisture availability in communities increases in the order presented in Tables 3 and 4. Mean importance values for all trees and the most common shrubs are plotted as a function of increasing moisture availability. Certain trees cluster at a given end of the spectrum; *A. concolor*, *P. pungens*, and *P. menziesii* are common only in moist situations. *Pinus longaeva* is restricted to the most arid sites. *Juniperus scopulorum* and *P. flexilis* occur at somewhat constant levels throughout, although both diverge from this pattern by decreasing in a given area. *Pinus ponderosa*, although uncommon in the most xeric area, generally decreases with increasing moisture levels.

For shrubs the pattern is similar though more complex. *Acer glabrum*, *J. communis*, and *M. repens* increase with moisture levels; *A. patula* decreases, *C. martinii* remains constant. However, *A. utahensis* and *C. montanus* both demonstrate substantial increases in the Pipo-Arpa type, Cemo phase, apparently at the expense of *A. patula* and *M. repens*.

From this it can be concluded that gradients of moisture availability are involved in sorting species into communities. However, moisture is not always the factor of paramount importance. Differences in substrate may be responsible for part of the pattern, especially in the increased abundance of *A. utahensis* and *C. montanus* in one given type. Only a complete ecological survey of the area will provide an answer to this question.

Distribution of Endemic Species

Species endemic to southern Utah and found within the main amphitheater are listed in Table 5, along with their ecological distribution within the study area. Also given for each species is its current status (Federal Register, 15 Dec. 1980, vol. 45, No. 242). No status is given for *E. panguicense* var. *panguicense*, which, although restricted in range (Reveal 1965), is apparently not rare (Welsh et al. 1975, Welsh and Thorne 1979). Status is defined by the following categories.

Category 1. Information is presently on hand to support listing as endangered or threatened species.

Category 2. Information is available that indicates a probable appropriateness of listing, but sufficient information is not yet available to support listing as endangered or threatened.

TABLE 4. Distribution of most abundant shrubs as a function of moisture availability. Types and phases given as in Table 3.

Mean i.v.	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
0	+	+					+	+	+																			+					+	+								
1–10			+								+	+							+		+	+	+	+	+	+					+	+					+					
11–20				+	+	+				+					+			+		+															+				+			
21–30																													+	+												
31–40																																				+		+				
41–50																																								+	+	
51–60																	+																									
61–70																																										
71–80													+			+																										
81–90														+																												+
91–100																																										
101–110																																										
111–120																																										
121–130																																										
131–140																											+															
	Acgl						Amut						Arpa						Cema						Cemo						Juco						Mare					

Category 3c. Taxa proven to be more abundant or widespread than previously considered. Not under consideration at the present time.

From Table 5 it may be seen that 9 of the 11 species listed occur in the Pilo type, 3 are found in the Pipo-Arpa type, and 2 occur in the MC type. Two species, *Oxytropis jonesii* and *Psoralea pariensis*, were not found in a recognizable vegetative type. Species that occur only in the Pilo type have the narrowest geographic distributions, although *Eriogonum panguicense* var. *panguicense* is an exception. It evidently has broader ecological tolerance inasmuch as it has been observed in several additional portions of Bryce Canyon. The narrow distributions of most of these species is no doubt a function of the uncommon occurrence of *P. longaeva* communities or other similar habitat throughout the High Plateaus.

Within Bryce Canyon, most of these endemics are restricted to the Claron formation. In this study, however, *Draba subalpina*, *Lesquerella rubicundula*, and *Townsendia minima* were observed on Quarternary alluvium, a formation from which they have not previously been reported. *Oxytropis jonesii*, *P. pariensis*, and *E. panguicense* are not limited to the Claron formation throughout their geographic range. The remainder of the endemics have been reported only from the Claron formation.

The majority of the vast number of endemic species found in southern Utah are restricted to substrates derived from a specific geologic formation (Welsh 1979). Welsh notes that most of these taxa are found in areas of exposed parent material; soil development provides a barrier between plant and substrate. In the main amphitheater, soils are well defined only in the Pipo-Psme type. It is significant that no endemic species occur in this type.

The distribution of endemic species in Utah is not a random one; fine-textured substrates support more species than coarser

TABLE 5. Distribution of endemic species in the main amphitheater.

Species	Status[1]	Distribution in[2] Utah (counties)	Geologic distribution[3]	Ecologic distribution in main amphitheater
Castilleja revealii	1	Garfield	R; W	Pilo type; washes, clay-limestone slopes
Cryptantha ochroleuca	1	Garfield	R; W	Pilo type; clay-limestone slopes
Draba subalpina	3c	Garfield, Iron, Kane, Millard	R; W; QA	Pipo-Arpa type, Pilo type, MC type
Eriogonum panguicense var. *panguicense*	—	Garfield, Iron, Kane, Sevier, Washington	R; W[4]	Pilo type, clay-limestone slopes
Lesquerella rubicundula	2	Garfield	R; W; QA	Pipo-Arpa type, Pilo type, clay-limestone slopes
Lomatium minimum	1	Garfield, Iron, Kane	R; W	Pilo type, clay-limestone slopes
Oxytropis jonesii	3c	Emery, Garfield, Uintah	W; Flagstaff limestone, Green River shale	Sand-limestone slopes
Penstemon bracteatus	1	Garfield	R	Pilo type, clay-limestone slopes
Psoralea pariensis	1	Garfield, Kane	R; alluvium and sandy alluvium	clay-limestone slopes
Silene pettersonii var. *minor*	1	Garfield, Iron	R	Pilo type, clay-limestone slopes
Townsendia minima	2	Garfield, Kane	R; W; QA	Pilo type, Pipo-Arpa type, MC type

[1]See text for discussion.
[2]From: Reveal 1965, Welsh et al. 1975, Welsh 1978a, Welsh and Thorne 1979.
[3]Refers to the entire range of species. From: Welsh 1978a, Welsh and Thorne 1979, personal observations. R = Red beds of Claron formation; W = White beds, QA = Quarternary alluvium.
[4]Reveal (1965) defines the typical substrate of the species only by the designation "clay slopes." With its wide geographic range it probably occurs on substrates other than those derived from the Claron formation.

ones, and desert and foothill vegetation is richer in endemic species than montane communities (Welsh 1978b, 1979). Based on these observations, Welsh has developed a "predictive model for establishing priority areas for the study of endangered and threatened plants of Utah," in which the highest priority is assigned to fine-textured soils supporting pinyon-juniper or desert shrub vegetation. A similar model may now be established for endemics of the Claron formation. Outcrops of this formation supporting communities of bristlecone pine are most likely to contain endemic species. Based on this assumption, populations of these species have been found at several locations in Bryce Canyon. Species generally restricted to such habitat conditions are likely to be less widely distributed than those capable of invading other communities on the Claron limestone. Higher priority for listing as threatened or endangered species should be assigned to those taxa concentrating in such habitat. The protection of sites containing populations of bristlecone pine promises to be the most productive strategy for ensuring the continued survival of these plants.

Stands of *P. longaeva* within Bryce Canyon National Park are of critical importance to botanical science. In addition to representing the preferred habitat of several endemic species, they are of interest as subalpine vegetation found at atypical elevations. Additional investigation of such areas is likely to be fruitful in studies of the population biology of endemic species and the environmental factors that govern plant distribution.

Within the main amphitheater, the heavy use by visitors does not seem to present any danger to plant populations. The only activities are hiking and horseback riding, both restricted to established trails. Few seem to stray from the trails because the steep topography makes getting lost or injured a high probability. By preventing expansion of the existing trail system, park officials can likely maintain species populations at the present levels.

Summary

An investigation on plant community structure in the main amphitheater of Bryce Canyon National Park has shown that the vegetative community previously referred to as the "breaks" is divisible into discrete vegetative types. Although most of the area consists of sparsely vegetated cliffs and slopes, well-defined communities are found on gentle lower slopes, rolling badlands, and canyon bottoms. Four major types are recognized, some being further divided into phases. Each has been characterized as to canopy, understory vegetation, and relationship to other types. A checklist of all species found in the area is given in the Appendix.

The ecologic distribution of several endemic species of southern Utah is given. The *Pinus longaeva* type is shown to be the richest in rare plants. This habitat is also unique in that it contains species normally found at subalpine elevations. It is predicted that endemic species of the Claron formation will tend to cluster in similar habitat. Protection of bristlecone pine communities is urged as the simplest means of providing protection for these rare plants.

Appendix

Checklist of species and their ecological distribution in the main amphitheater, Bryce Canyon National Park. I = Pipo-Arpa type, II = Pipo-Psme type, III = MC type, IV = Pilo type, V = washes, clay and talus slopes. ° = additions to the flora of the Kaiparowitz Basin.

	Vegetative type				
Species	I	II	III	IV	V
Aceraceae					
Acer glabrum Torr.	+	+	+		+
Apiaceae (Umbelliferae)					
Cymopterus purpureus Wats.	+	+	+	+	+
Lomatium minimum (Mathias) Mathias				+	+

Appendix continued.

Species	Vegetative type				
	I	II	III	IV	V
APOCYNACEAE					
Apocynum androsaemifolium L.		+		+	+
ASCLEPIDACEAE					
Asclepias asperula (Decne) Woodson	+				
ASTERACEAE (Compositae)					
Aster glaucodes Blake	+	+	+		+
Chrysothamnus nauseosus (Pallas) Britt.	+				+
C. parryi (Gray) Greene	+				+
Cirsium arizonicum (Gray) Petrak	+	+	+	+	+
Erigeron simplex Greene°				+	+
Haplopappus armerioides (Nutt.) Gray	+	+	+	+	+
Hymenopappus filifolius Hook.	+	+	+	+	+
Hymenoxys acaulis (Pursh) Parker	+			+	+
H. richardsonii (Hook.) Cockerell					+
Leucelene ericoides (Torr.) Greene	+				
Machaeranthera grindelioides (Nutt.) Shinners	+	+	+	+	+
Petradoria pumila (Nutt.) Greene	+		+		+
Senecio attratus Greene°			+		+
S. multilobatus T. & G. ex Gray	+	+		+	
Solidago sparsiflora Gray	+	+	+		
Stephanomeria tenuifolia (Torr.) Hall	+				+
Tetradymia canescens DC.	+				+
Townsendia exscapa (Richards) T. C. Porter					+
T. minima Eastwood	+		+	+	+
Xanthocephalum sarothrae (Pursh) Shinners (= *Gutierrezia sarothrae* Pursh)	+			+	
BERBERIDACEAE					
Mahonia fremontii (Torr.) Fedde (= *Berberis fremontii* Torr.)	+				
M. repens (Lindl.) G. Don. (= *B. repens* Lindl.)	+	+	+	+	+
BETULACEAE					
Betula occidentalis Hook.			+		+
BORAGINACEAE					
Cryptantha abata Johnst.	+		+	+	
C. ochroleuca Higgins°				+	+
Lithospermum multiflorum T. & G.	+	+	+	+	
BRASSICACEAE (Cruciferae)					
Arabis pendulina Greene	+				
Descurainia sophia (L.) Webb. ex Engler & Prantl.					+
Draba subalpina Goodmn. & Hitchc.	+		+	+	
Lesquerella rubicundula Rollins	+			+	+
Physaria chambersii Rollins	+		+	+	+
Streptanthus cordatus Nutt. ex T. & G.	+				
Thlaspi arvense L.					+
CAPRIFOLIACEAE					
Sambucus caerulea Raf.	+	+	+		+
Symphoricarpos oreophilus Gray	+	+	+		+
CARYOPHYLLACEAE					
Arenaria fendleri (Rydb.) Fern.			+		
Silene pettersonii Maguire var. *minor* Hitchc. & Maguire				+	+
CORNACEAE					
Cornus stolonifera Michx.°					+
CUPRESSACEAE					
Juniperus communis L.	+	+	+	+	+
J. osteosperma (Torr.) Little	+				+
J. scopulorum Sarg.	+	+	+	+	+

Appendix continued.

Species	Vegetative type I	II	III	IV	V
ERICACEAE					
Arctostaphylos patula Greene	+	+	+	+	+
ELAEAGNACEAE					
Shepherdia canadensis (L.) Nutt.		+	+		
EUPHORBIACEAE					
Euphorbia fendleri T. & G.	+				
E. lurida Engelmn. ex Ives°	+	+	+	+	+
FABACEAE (Leguminosae)					
Astragalus convallarius Greene°	+	+	+		
A. kentrophyta Gray			+		+
A. megacarpus (Nutt.) Gray	+		+		+
Oxytropis jonesii Barneby					+
Psoralea pariensis Welsh & Atwood°					+
FAGACEAE					
Quercus gambelii Nutt.	+	+	+		
GENTIANACEAE					
Gentianella tenella (Rottb.) Borner° (= *Gentiana tenella* Rottb.)		+		+	+
Swertia radiata (Kellogg) Kuntze°	+	+	+	+	
LAMIACEAE (Labiatae)					
Monardella odoratissima Benth.				+	+
LINACEAE					
Linum kingii Wats.	+		+	+	+
L. perenne L. var. *lewisii* (Pursh) Eat. & Wright	+		+		+
ONAGRACEAE					
Calylophus lavandulaefolia (T. & G.) Raven (= *Oenothera lavandulaefolia* T. & G.)	+			+	+
Oenthera brachycarpa (Gray) Britt.	+	+	+	+	+
PINACEAE					
Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.	+		+		+
Picea pungens Engelmn.	+	+	+	+	+
Pinus edulis Engelmn. & Wisliz.	+				+
P. flexilis James ex Long	+	+	+	+	+
P. longaeva D. K. Bailey	+		+	+	+
P. ponderosa Dougl. ex Lawson	+	+	+	+	+
Pseudotsuga menziesii (Mirb.) Franco	+	+	+	+	+
POACEAE (Gramineae)					
Agropyron cristatum (L.) Gaertn.					+
A. scribneri Vasey°				+	+
A. trachycaulum (Linke) Malte					+
Calamagrostis scopulorum Jones			+		+
Elymus salina Jones	+	+	+	+	+
Oryzopsis hymenoides (R. & S.) Ricker ex Piper	+	+	+	+	+
Poa compressa L.°					+
Puccinellia nuttalliana (Schult.) Hitchc. ex Jeps.					+
Schizachyrium scoparium (Michx.) Nash ex Small°	+				
Sitanion hystrix (Nutt.) J. G. Smith	+				+
Stipa columbiana Macoun°	+				+
POLEMONIACEAE					
Phlox austromontana Cov.	+			+	+
POLYGONACEAE					
Eriogonum corymbosum Benth.					+
E. panguicense (Jones) Reveal var. *panguicense*				+	+
RANUNCULACEAE					
Aquilegia scopulorum Tidestr.	+		+	+	+
Clematis columbiana (Nutt.) T. & G. (= *C. pseudoalpina* (Kuntze) A. Nels.)	+	+	+	+	

Appendix continued.

Species	Vegetative type				
	I	II	III	IV	V
RHAMNACEAE					
Ceonothus martinii Jones	+	+	+	+	+
ROSACEAE					
Amelanchier utahensis Koehn	+	+	+		+
Cercocarpus ledifolius Nutt.°			+	+	
C. montanus Raf.	+	+	+	+	+
Holodiscus dumosus (Nutt.) Heller			+	+	+
Ivesia sabulosa (Jones) Keck	+			+	+
Potentilla fruticosa L.°				+	+
Purshia tridentata (Pursh) DC.	+	+	+	+	+
SALICACEAE					
Populus angustifolia James ex Torr.			+		+
P. tremuloides Michx.					+
Salix exigua Nutt.					+
SAXIFRAGACEAE					
Ribes cereum Dougl.		+	+		+
SCROPHULARIACEAE					
Castilleja linariaefolia Benth. ex DC.	+	+			+
C. revealii N. Holmgren			+	+	
Pedicularis centranthera Gray ex Torr.	+	+	+	+	
Penstemon bracteatus Keck				+	+

LITERATURE CITED

ANDERSON, J. J., AND P. D. ROWLEY. 1975. Cenozoic stratigraphy of southwestern high plateaus of Utah. Pages 1–51 *in* Cenozoic geology of southwestern high plateaus of Utah. Geol. Soc. Amer., Special Paper 160.

BAILEY, D. K. 1970. Phytogeography and taxonomy of *Pinus*, subsection *Balfourianae*. Ann. Missouri Bot. Gard. 57:210–249.

BROX, G. S. 1961. The geology and erosional development of northern Bryce Canyon National Park. Unpublished thesis, Univ. of Utah, Salt Lake City.

BUCHANAN, H. 1960. The plant ecology of Bryce Canyon National Park. Unpublished dissertation, Univ. of Utah, Salt Lake City.

BUCHANAN, H., AND R. GRAYBOSCH. 1981. Revised checklist of the vascular plants of Bryce Canyon National Park, Utah. Great Basin Nat. 41:109–120.

CRONQUIST, A., A. H. HOLMGREN, N. H. HOLMGREN, AND J. L. REVEAL. 1972. Intermountain flora, Vol. 1. Hafner Publ. Co., New York.

DIXON, H. 1935. Ecological studies on the high plateaus of Utah. Bot. Gaz. 97:272–320.

DOELLING, H. H. 1975. Geology and mineral resources of Garfield Co., Utah. Utah Geol. and Min. Survey, Bull. 107.

ELLISON, L. 1954. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Mon. 24:89–184.

HARRINGTON, H. D. 1954. Manual of the plants of Colorado. Sage Books, Denver.

LAMARCHE, V. C. 1969. Environment in relation to age in bristlecone pines. Ecology 50:53–59.

LINDQUIST, R. C. 1977. The geology of Bryce Canyon National Park. Bryce Canyon Natural History Assoc., Bryce Canyon, Utah.

______. 1980. Slope processes and forms at Bryce Canyon National Park. Unpublished dissertation. Univ. of Utah, Salt Lake City.

REVEAL, J. L. 1965. Notes on three Utah *Eriogonums*. Proc. Utah Acad. Sci. 42:287–292.

SORENSEN, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Kong. Dan Vidensk. Biol. Skr. 5:1–34.

WELSH, S. L. 1978a. Utah flora: Fabaceae (Leguminosae). Great Basin Nat. 38:225–367.

______. 1978b. Problems in plant endemism on the Colorado Plateau. Great Basin Nat. Mem. No. 2: 191–196.

______. 1979. Endangered and threatened plants of Utah: a case study. Great Basin Nat. Mem. No. 3:69–80.

WELSH, S. L., AND G. MOORE. 1973. Utah plants: Tracheophyta. Brigham Young University Press, Provo, Utah.

WELSH, S. L., N. D. ATWOOD, AND J. L. REVEAL. 1975. Endangered, threatened, extinct, endemic, and rare or restricted Utah vascular plants. Great Basin Nat. 35:327–376.

WELSH, S. L., N. D. ATWOOD, AND J. R. MURDOCK. 1978. Kaiparowitz flora. Great Basin Nat. 38:125–179.

WELSH, S. L., AND K. H. THORNE. 1979. Illustrated manual of proposed endangered and threatened plants of Utah. U.S. Fish and Wildlife Service, Denver, Colorado.

WELSH, S. L., N. D. ATWOOD, S. GOODRICH, E. NEESE, K. H. THORNE, AND B. ALBEE. 1981. Preliminary index of Utah vascular plant names. Great Basin Nat. 41:1–108.